AMSR Land Surface Soil Moisture Combined Product

NPD and SCA Algorithms

Steven Chan, Mariko Burgin, Eni Njoku
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Rajat Bindlish, Tom Jackson
USDA ARS Hydrology & Remote Sensing Laboratory, Beltsville, MD

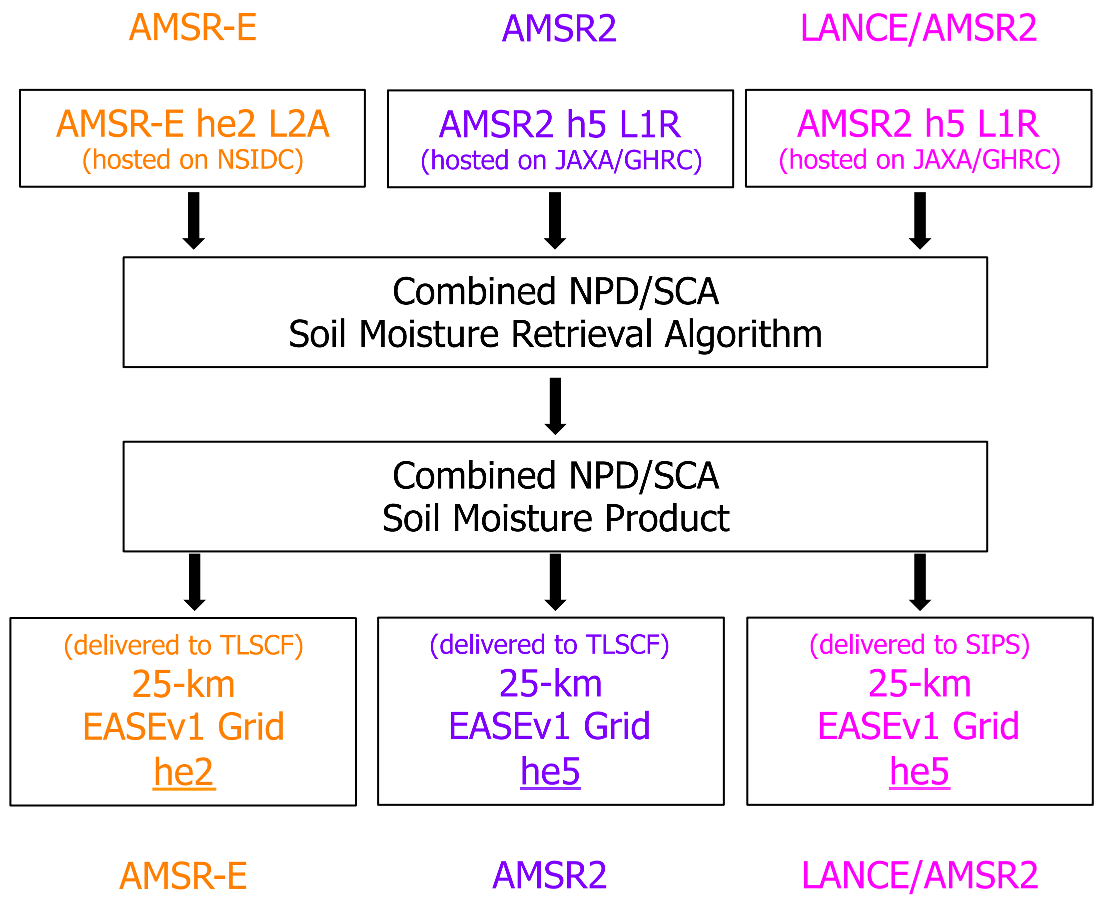
Talk Outline

- Introduction - *Chan*
- Integrated software development - *Chan*
- SCA overview and progress - *Bindlish*
- NPD overview and progress - *Njoku*
- Concluding Remarks - *All*

Introduction

- The AMSR-E and AMSR2 L2 and L3 soil moisture products include soil moisture values derived from two separate algorithms (NPD and SCA)
  - NPD = Normalized Polarization Difference, developed at JPL
  - SCA = Single Channel Algorithm, developed at USDA/ARS/HRSL
- NPD and SCA codes are integrated into one software package at JPL and delivered to the TLSCF
- The combined code is implemented on operational processors for:
  - Aqua/AMSR-E end-of-mission processing
  - GCOM-W/AMSR2 processing
  - GCOM-W/AMSR2 LANCE processing

AMSR-E/AMSR2 Parallel Work



Integrated Software Development

Steven Chan et al.

AMSR-E/AMSR2 NPD/SCA SW Development

Milestones	Timeline	Status
AMSR-E NPD/SCA Soil Moisture SW Development & Testing	Oct 2014	✓
AMSR-E NPD/SCA Soil Moisture SW Delivery Documentation	Nov 2014	✓
AMSR-E NPD/SCA Soil Moisture SW Delivery to TLSCF	Nov 2014	✓
AMSR2 NPD/SCA Soil Moisture SW Development & Testing ▪ AMSR2 L1R input module completed ▪ Ancillary data integration completed ▪ NPD/SCA inversion modules completed ▪ he5 output module incomplete due to unresolved HDF-EOS5 library calls	Nov 2015	Work in progress

AMSR2 NPD/SCA Soil Moisture SW Environment

To main consistency, both NPD and SCA codes were developed in the same software development environment.

Operating system:

Red Hat Enterprise Linux release 6.2

Fortran complier:

gcc 4.5.2

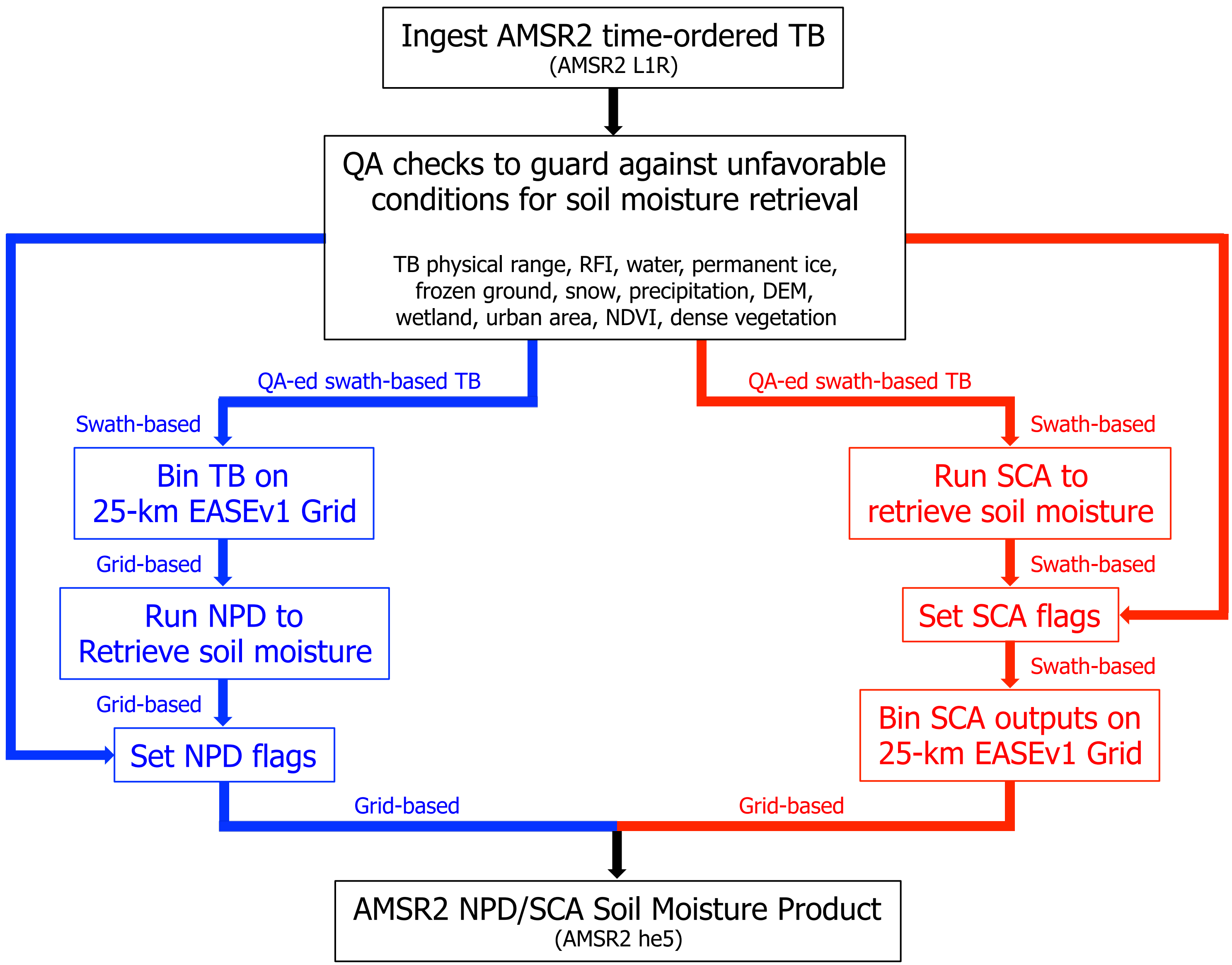
HDF5/HDFEOS5 libraries:

hdf5-1.8.11 (built with gcc 4.5.2)
hdfeos5.1.14 (built with gcc 4.5.2)

PGE interface to SIPS:

aeland2_main.exe <Input L1R file> <Ancillary Dir> <Output L2B Dir> <PGE version>

AMSR2 NPD/SCA Soil Moisture SW Flowchart

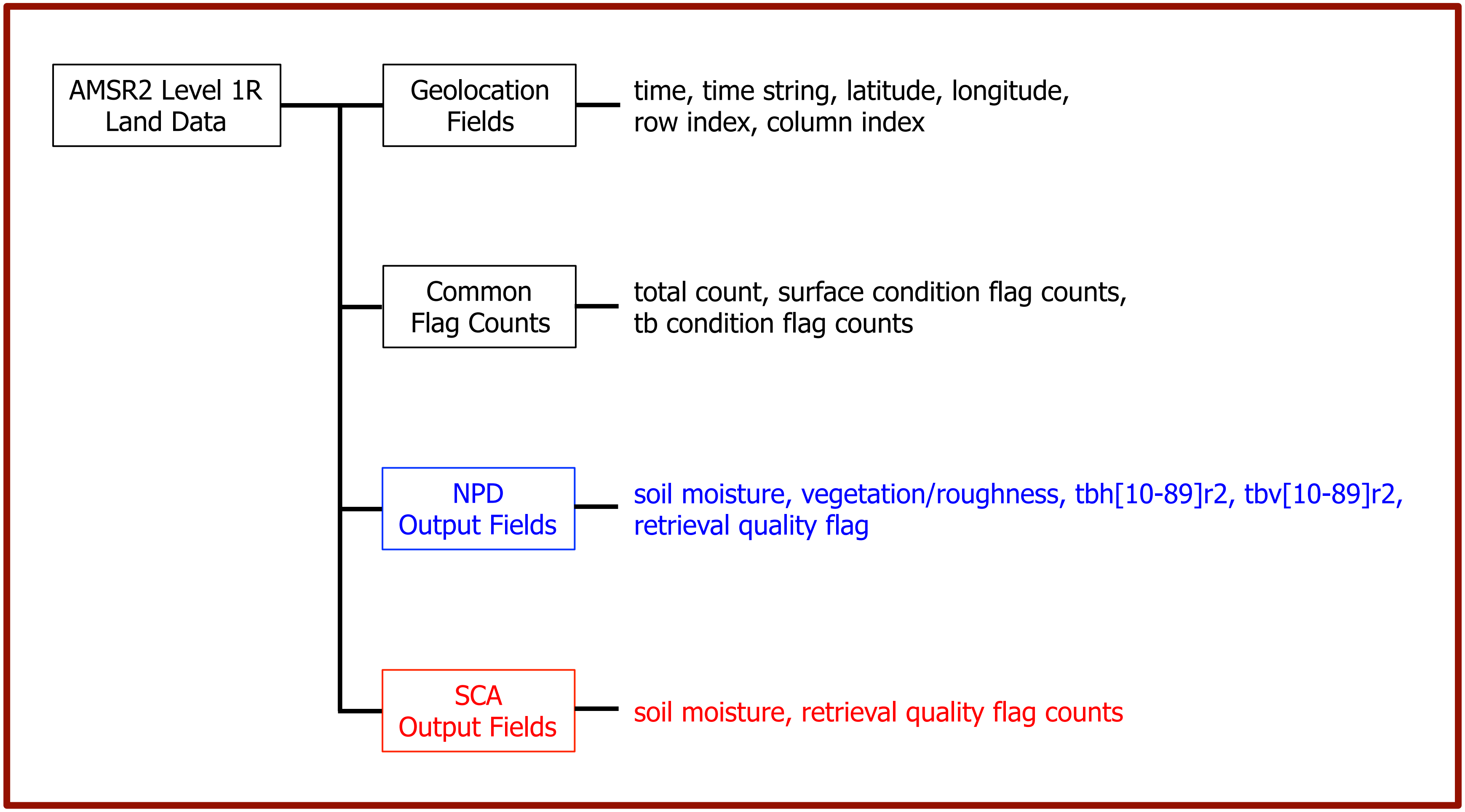


AMSR2 NPD/SCA Soil Moisture SW Ancillary Data

Ancillary Parameters	Source	Purpose	NPD	SCA
Static water fraction	MODIS	Mask out water where retrieval is not attempted	✔	✔
Land cover classification	MODIS	Mask out wetlands, urban area, and permanent ice where retrieval is not attempted	✔	✔
DEM statistics	GMTED	Mask out mountainous terrain where retrieval is not attempted	✔	✔
NDVI climatology	MODIS	Mask out dense vegetation where retrieval is not attempted	✔	✔
		Provide vegetation correction in soil moisture retrieval		✔
Soil texture	HWSD	Provide input to soil dielectric model		✔
Soil temperature	AMSR TB	Provide surface temperature correction in soil moisture retrieval		✔
Reference NPD	AMSR TB	Provide minimum NPD in soil moisture retrieval	✔	
25-km EASEv1 Grid Latitude/longitude	NSIDC	TB binning using inverse-distance squared weighting	✔	
Minimum soil moisture	Scaled Nature Run (from Reichle et al.)	Provide soil moisture lower bound	✔	
Model coefficients	JPL	Enable global fine tuning of retrieval algorithm	✔	

AMSR2 NPD/SCA Soil Moisture SW Output Structure

AMSR2's he5 granule shares the same structure as AMSR-E's he2 granule



SCA (USDA): Single Channel Algorithm

Rajat Bindlish, Tom Jackson

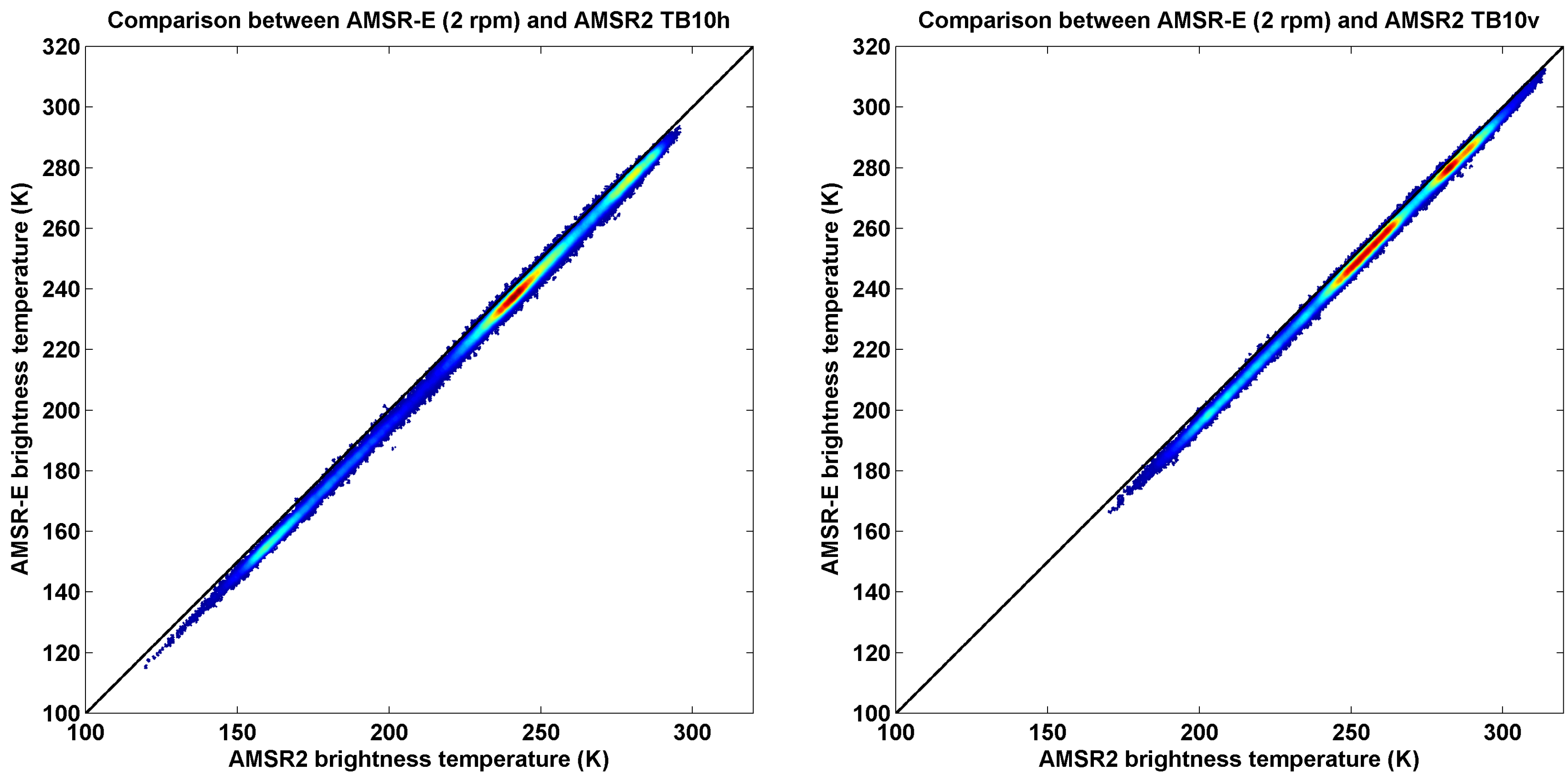
Outline

- Brightness Temperature inter-comparison between AMSR-E and AMSR2
- SCA Soil Moisture results
  - Algorithm flowchart
  - Transferability from AMSR-E to AMSR2
  - Preliminary validation

SCA: Transferability to AMSR2

- Theoretically SCA can be applied directly and without modifications to AMSR2 given that AMSR-E and AMSR2 TB are consistent.
- Conducted an inter-comparison analysis to establish the consistency of the TB data and the SCA retrievals.

AMSR-E and AMSR2 TB
Global TB inter-comparisons, 2rpm



Comments

- Colocated TB observations between AMSR-E and AMSR2
  - Boresight distance of less than 1 km
  - Time less than 5 min (both in A-train)
- Current results with Dec 2012-Feb 2013 data (will be extended to the complete time series in future)

Comparison between AMSR-E (2 rpm) and AMSR2 over Land

Summary Statistics

		RMSD (K)	R	Bias [AMSR2-AMSR-E] (K)	N
H pol	6.9 GHz	1.97	0.9992	1.07	545056
	10 GHz	4.13	0.9992	3.77	522519
	18 GHz	2.06	0.9990	0.46	526352
	23 GHz	2.62	0.9990	1.95	551870
	36 GHz	3.99	0.9978	3.13	694179
V pol	6.9 GHz	1.36	0.9991	0.07	547543
	10 GHz	3.49	0.9990	3.15	524774
	18 GHz	2.52	0.9988	1.29	528564
	23 GHz	2.32	0.9989	1.84	553709
	36 GHz	3.80	0.9978	3.18	696657

V2.0

Re-calibration of AMSR2 using AMSR-E (2 rpm)

V2.0

		Gain (m)	Offset (c)
H pol	6.9 GHz	1.0067	-2.4411
	10 GHz	0.9982	-3.0265
	18 GHz	1.0044	-1.2227
	23 GHz	1.0078	-3.6261
	36 GHz	0.9993	-2.8160
V pol	6.9 GHz	1.0121	-2.8423
	10 GHz	1.0105	-5.2327
	18 GHz	1.0113	-4.5642
	23 GHz	1.0045	-2.9047
	36 GHz	1.0047	-3.8401

•These gain and offset numbers were computed using co-located AMSR-E and AMSR2 observations (both land and ocean). Assuming AMSR-E (2 rpm) calibration was perfect.

•Best to constrain the low TB end using cold sky calibration from both the sensors. Gain and offset should be re-computed after constraining the low end.

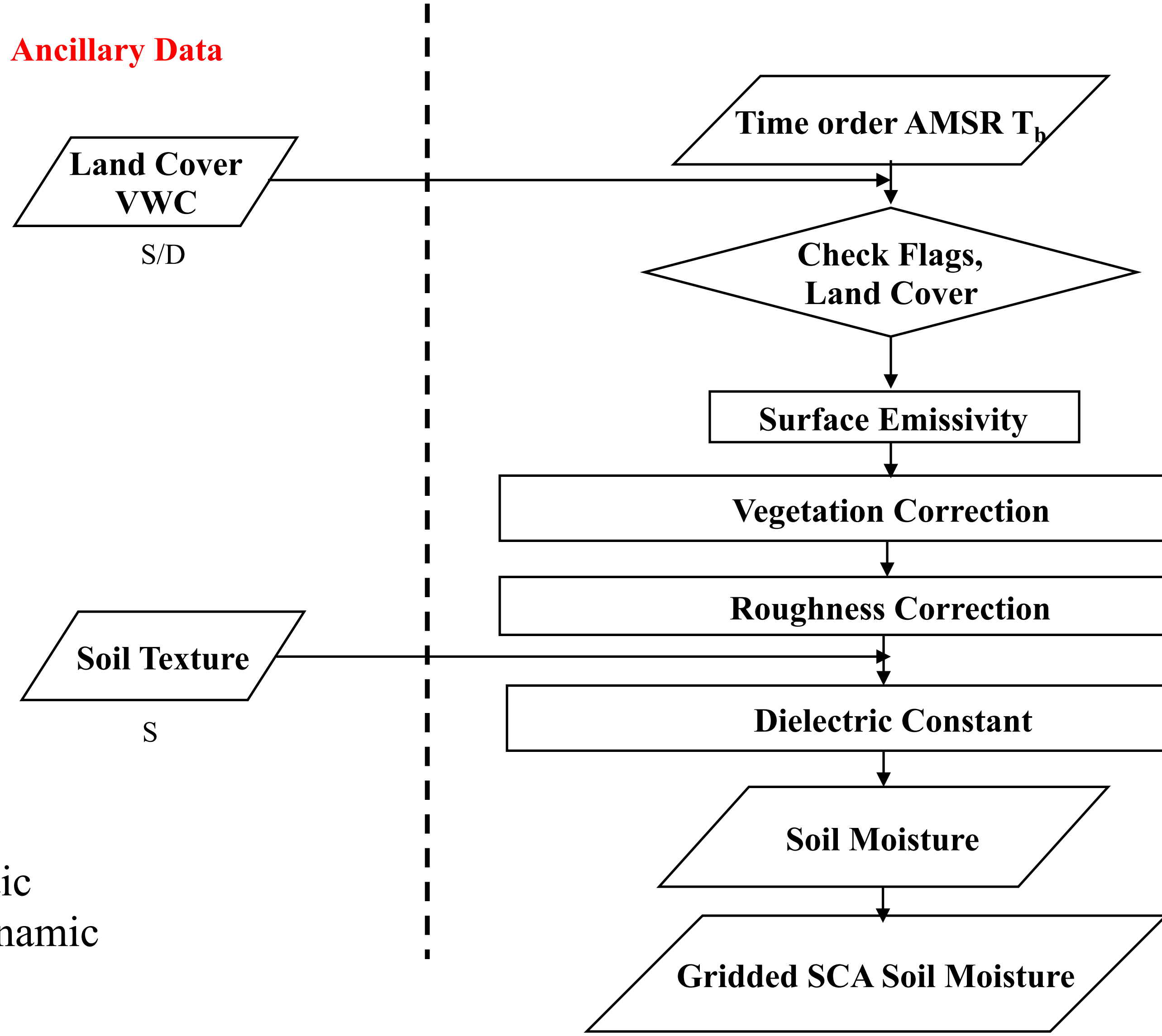
Summary of TB inter-comparison

- Colocated AMSR2 and AMSR-E (2 rpm) observations were compared
  - Significant differences (positive bias) remain between the two observations (based on 3 month analysis)
  - The warm bias is consistent for all the channels
- Implications on the calibration of AMSR2 and AMSR-E (operational mode) are unknown
- A warm bias of 2-4K in 10 GHz h-pol will have an impact on the soil moisture retrievals
- How do these differences impact the other environmental records?
- These differences may have implications on the development of the long-term environmental records (soil moisture and others)

Outline

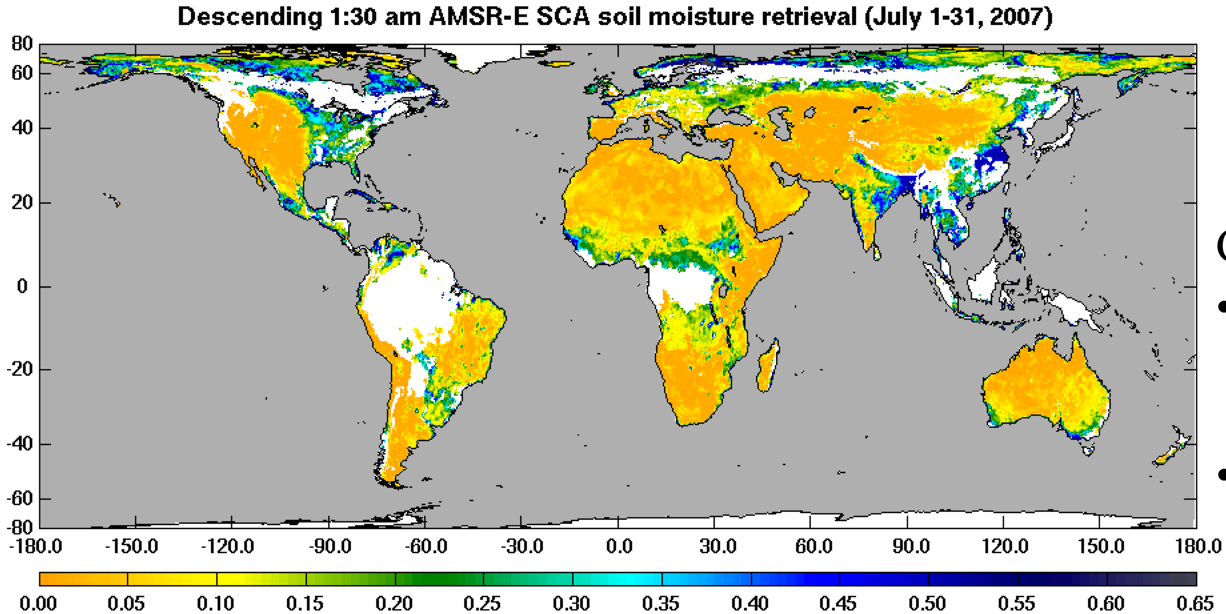
- Brightness Temperature inter-comparison between AMSR-E and AMSR2
- SCA Soil Moisture results
  - Algorithm flowchart
  - Transferability from AMSR-E to AMSR2
  - Preliminary validation

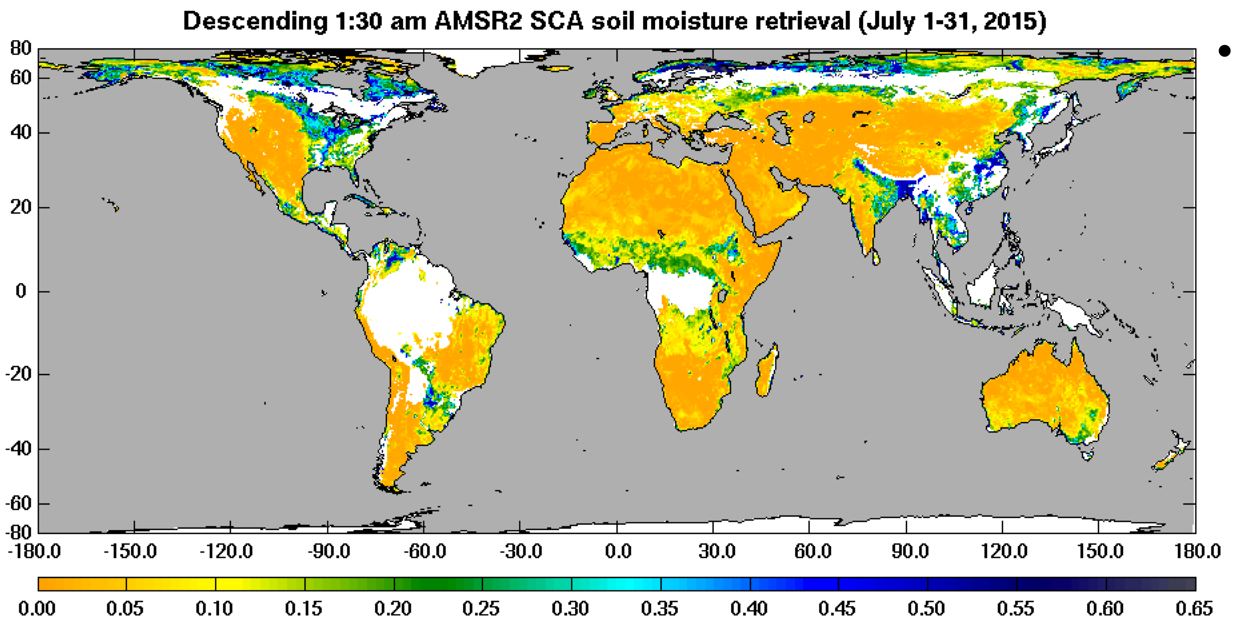
SCA Soil Moisture Retrieval



S-Static
D-Dynamic

AMSR-E and AMSR2 SCA VSM



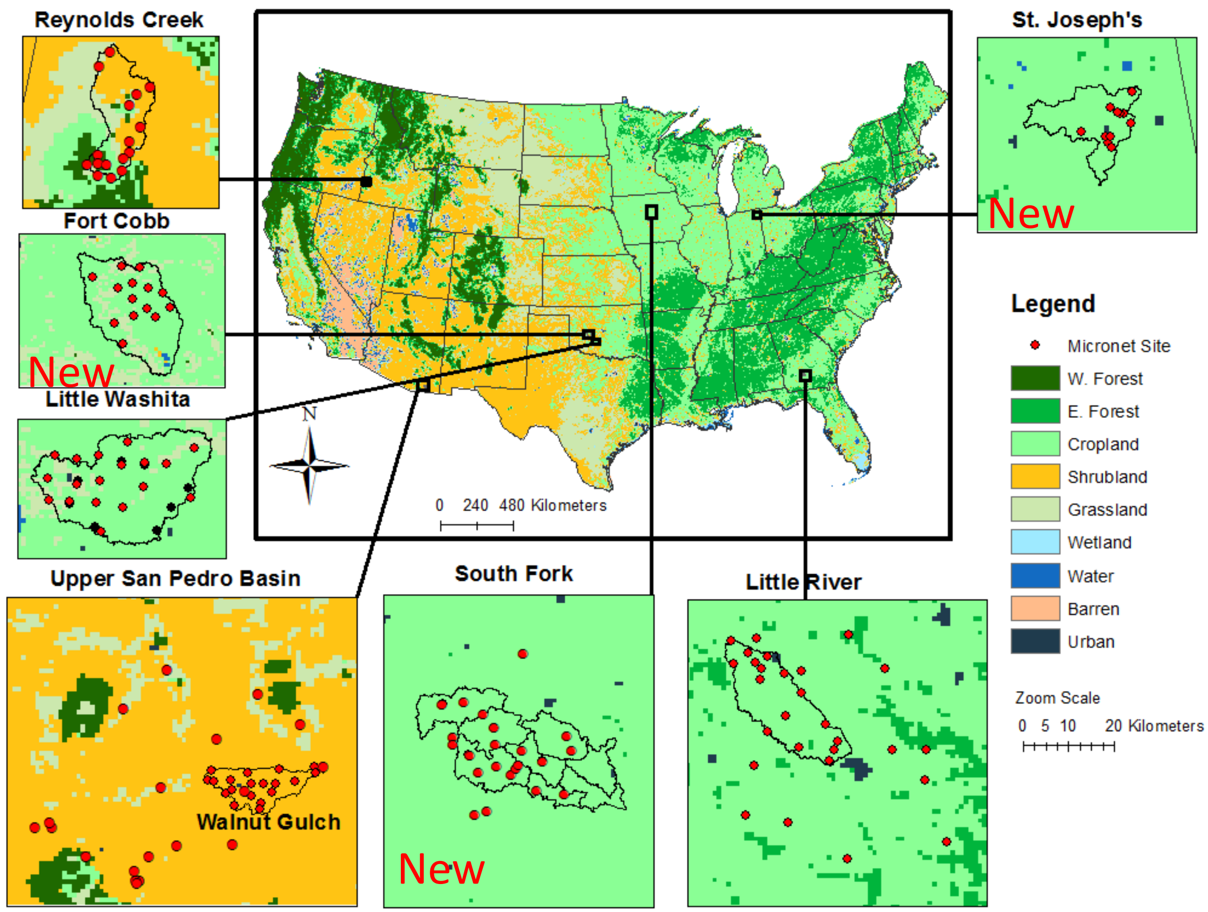


Comments

- Global soil moisture maps. Data represent long term averages for the month of July.
- Maps show similar spatial structure and consistency between the two SCA retrievals.
- Areas with dense vegetation masked out.

USDA ARS Validation Sites

- Continuing record for the *four* USDA ARS sites distributed across the U.S. in different climate regions providing surface soil moisture (Since 2002).
- Three new sites available for AMSR2. ***SJ and SF may exceed vegetation limits of AMSR2 algorithms.***



Impact of AMSR2 L1 Data Version on SCA SM Retrievals

Site	Statistic	Ascending orbit (1:30 PM)		Descending orbit (1:30 AM)	
		SCA V2	SCA V2adj	SCA V2	SCA V2adj
LR	R	0.615	0.640	0.509	0.524
	RMSD	0.033	0.040	0.038	0.054
	Bias	-0.001	0.024	0.012	0.041
	ubRMSD	0.033	0.032	0.036	0.035
LW	R	0.505	0.532	0.366	0.412
	RMSD	0.083	0.061	0.084	0.065
	Bias	-0.065	-0.035	-0.067	-0.042
	ubRMSD	0.051	0.050	0.050	0.050
WG	R	0.250	0.391	0.550	0.628
	RMSD	0.073	0.065	0.067	0.058
	Bias	-0.066	-0.057	-0.059	-0.050
	ubRMSD	0.032	0.031	0.030	0.029
RC	R	0.587	0.633	0.563	0.582
	RMSD	0.083	0.069	0.081	0.070
	Bias	-0.078	-0.064	-0.076	-0.064
	ubRMSD	0.029	0.027	0.029	0.027
FC	R	0.605	0.661	0.585	0.635
	RMSD	0.080	0.060	0.072	0.053
	Bias	-0.062	-0.034	-0.054	-0.028
	ubRMSD	0.051	0.050	0.047	0.045
SJ	R	0.001	-0.039	0.035	-0.004
	RMSD	0.105	0.098	0.089	0.092
	Bias	-0.064	-0.042	-0.032	-0.011
	ubRMSD	0.083	0.088	0.083	0.091
SF	R	0.597	0.583	0.655	0.588
	RMSD	0.158	0.143	0.148	0.149
	Bias	-0.111	-0.092	-0.093	-0.089
	ubRMSD	0.112	0.110	0.115	0.119

Data Version	
SCA V2	SCA VSM using version V2 beta2 L1R data
SCA V2adj	SCA VSM using version V2 L1R data (with adjusted TB)

Statistics	
R	Correction Coefficient
RMSD	Root Mean Squared Difference (m3/m3)
Bias	[Retrieval-In Situ] (m3/m3)
ubRMSD	unbiased RMSD [Corrected only for bias. not corrected for gain and offset]

Comments

- AMSR2 data record: July 2012 - November 2014
- Applying an adjustment to the TB values (based upon our re-calibration) generally improves the retrievals.
- Further comparisons use the adjusted values.
- The performance in SF and SJ is poor. Attributed to vegetation (for now).

Comparison of SCA and JAXA SM Retrievals

Site	Statistic	Ascending orbit (1:30 PM)		Descending orbit (1:30 AM)	
		SCA V2adj	JAXA	SCA V2adj	JAXA
LR	R	0.640	0.553	0.524	0.347
	RMSD	0.040	0.041	0.054	0.063
	Bias	0.024	-0.017	0.041	0.013
	ubRMSD	0.032	0.038	0.035	0.062
LW	R	0.532	0.474	0.412	0.402
	RMSD	0.061	0.075	0.065	0.083
	Bias	-0.035	-0.043	-0.042	-0.070
	ubRMSD	0.050	0.061	0.050	0.045
WG	R	0.391	0.543	0.628	0.785
	RMSD	0.065	0.035	0.058	0.032
	Bias	-0.057	-0.018	-0.050	-0.017
	ubRMSD	0.031	0.030	0.029	0.027
RC	R	0.633	0.554	0.582	0.611
	RMSD	0.069	0.050	0.070	0.053
	Bias	-0.064	-0.040	-0.064	-0.044
	ubRMSD	0.027	0.030	0.027	0.030
FC	R	0.661	0.637	0.635	0.592
	RMSD	0.060	0.078	0.053	0.082
	Bias	-0.034	-0.065	-0.028	-0.071
	ubRMSD	0.050	0.043	0.045	0.041
SJ	R	-0.039	0.272	-0.004	0.421
	RMSD	0.098	0.127	0.092	0.126
	Bias	-0.042	-0.108	-0.011	-0.117
	ubRMSD	0.088	0.067	0.091	0.049
SF	R	0.583	0.602	0.588	0.517
	RMSD	0.143	0.179	0.149	0.180
	Bias	-0.092	-0.169	-0.089	-0.169
	ubRMSD	0.110	0.061	0.119	0.061

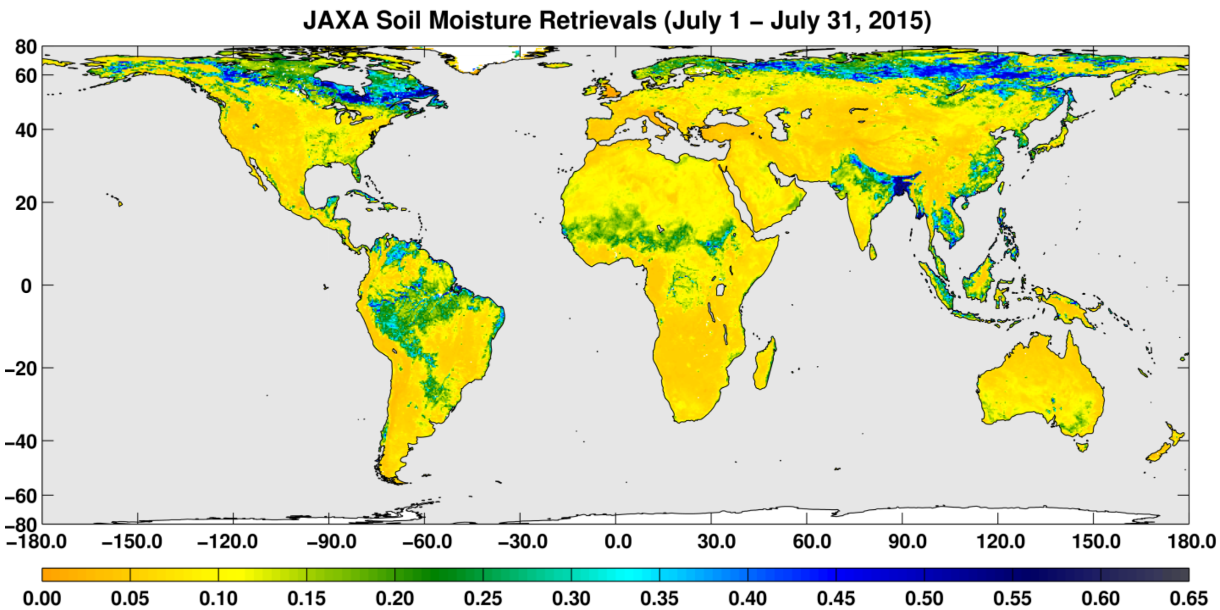
Data Version	
SCA V2adj	SCA VSM using version V2 L1R data (with adjusted TB)
JAXA	JAXA VSM

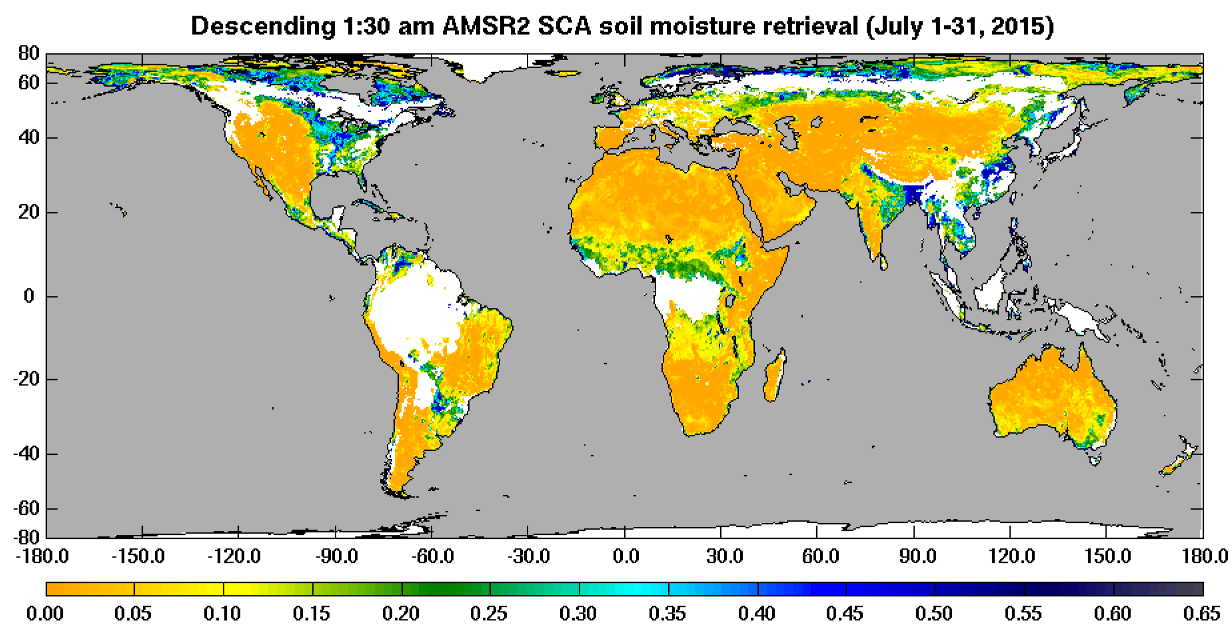
Statistics	
R	Correction Coefficient
RMSD	Root Mean Squared Difference (m3/m3)
Bias	[Retrieval-In Situ] (m3/m3)
ubRMSD	unbiased RMSD [Corrected only for bias. not corrected for gain and offset]

Comments

- AMSR2 data record: July 2012 - November 2014
- Overall: similar performance
- JAXA has lower bias for WG

AMSR2 VSM: JAXA and SCA

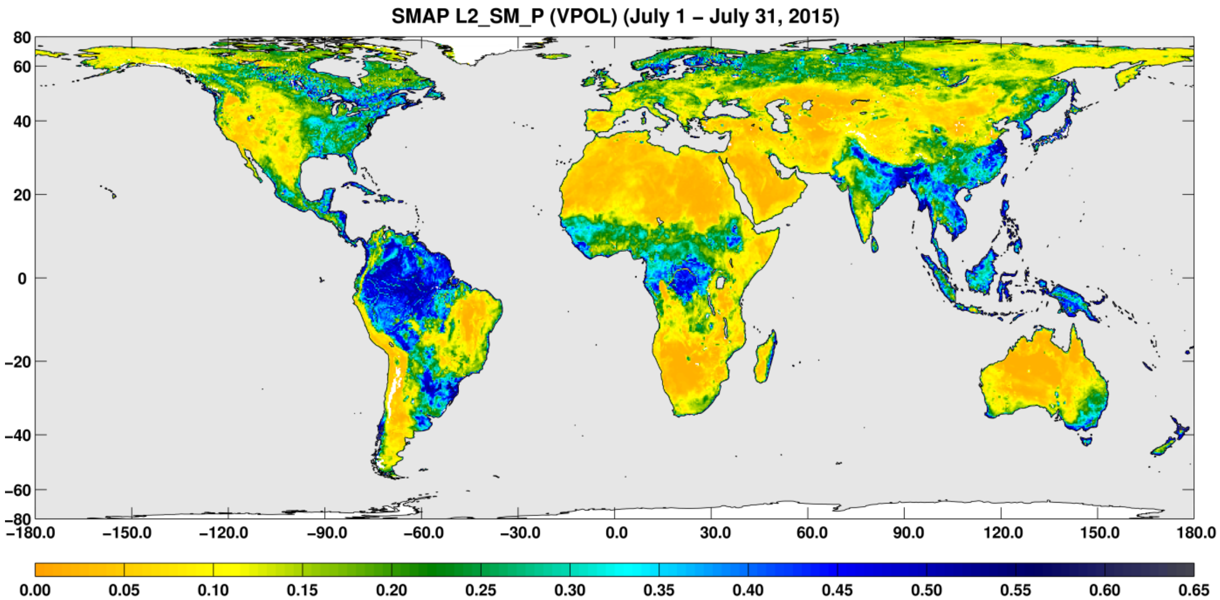


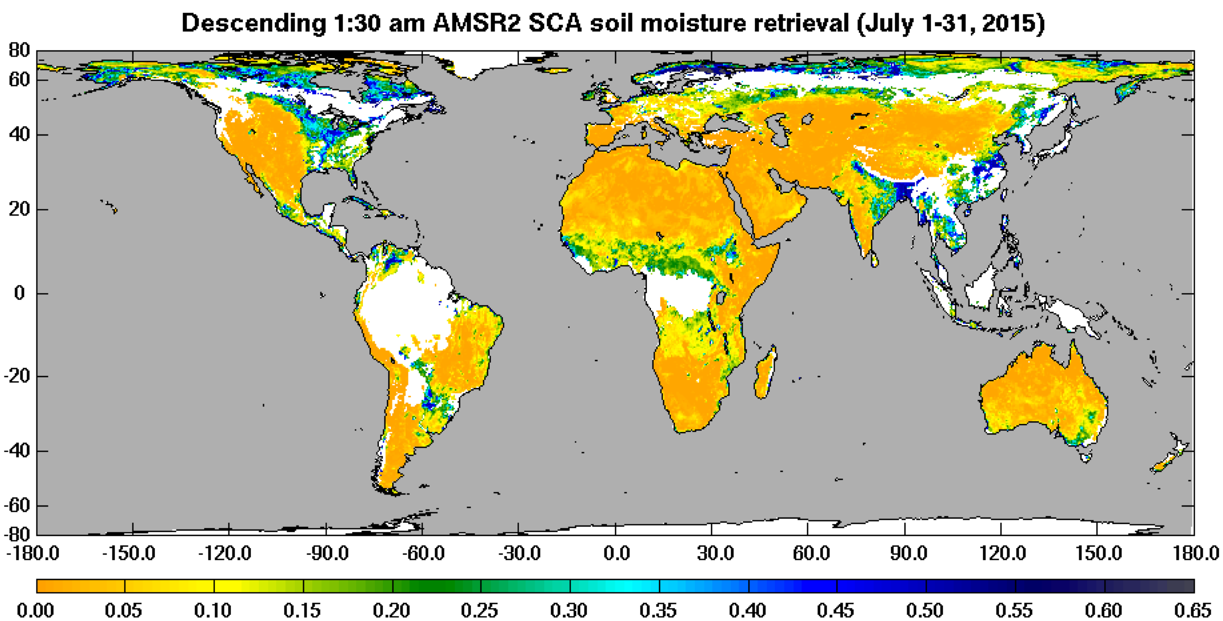


Comments

- Global soil moisture maps.
- Maps show spatial structure and consistency.
- Differences between the two satellite retrievals in areas of higher vegetation levels. JAXA tends to estimate dry soil moisture as compared to high VSM estimates for SCA retrievals.

SMAP and AMSR2 SCA VSM





Comments

- Global soil moisture maps.
- Maps show similar spatial structure and consistency between the two satellite retrievals.
- SMAP is L-band (greater penetration depth)
- SMAP flags (and performs) retrievals in dense vegetation conditions.
- Similar baseline soil moisture algorithm (SMAP: SCAV; AMSR: SCAH)
- Same ancillary data.

Summary

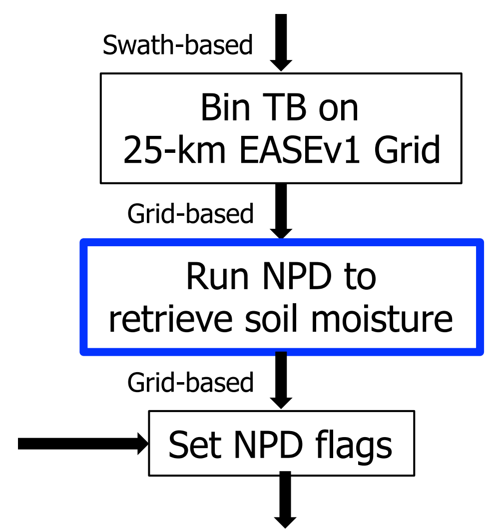
- SCA was successfully implemented with AMSR2
- Necessary to adjust TBs for gain and offset versus AMSR-E.
- Overall the performance levels of both algorithms are similar and meet requirements for low to moderate vegetation levels. Preliminary, needs further scrutiny.
- Initial evaluations using new US sites with higher vegetation levels indicates poor performance of AMSR2-based algorithms.
- Generating a consistent long-term soil moisture data record using data from AMSR-E and AMSR2: How do we rescale the final retrievals or the TB?
- Tuning of SCA retrieval parameters will improve the results.

NPD (JPL): Normalized Polarization Difference algorithm

Mariko Burgin, Eni Njoku, Steven Chan

NPD overview

- NPD uses Res 2 TB values from AMSR-E L2A and AMSR2 L1R
- Binning updated from direct mean to inverse distance squared
  - Consistent with SMAP & NSIDC binning approaches
- Ancillary data consist of monthly minimum reference NPD (NPD^{dry}) and baseline soil moisture from model-based Scaled Nature Run (Reichle et al.) ($mv^{soilmin}$)
- NPD coefficients are read in as five 2-D model coefficient arrays (a_0, a_1, a_2, b_0, b_1) (pixel-based)
- Flags used as previously discussed



Current NPD equations

(2) (3)

$$mv = mv^{soilmin} + a_1\,(NPD - NPD^{dry})\,\exp(a_2\, g)$$

(1) $$g = b_0 + b_1 \ln(NPD^{dry})$$

NPD $= (TB_V - TB_H)/(TB_V + TB_H)$

NPD^{dry} = monthly 3rd percentile min from 2002-2011 of AMSR-E data

monthly 3rd percentile min from 2013-2014 of AMSR2 data

Coefficient tuning (2-D arrays) is achieved in 3 steps:

(1) Vegetation factor
(2) Baseline (dry) soil moisture
(3) Departure from dry condition

Vegetation factor

$$mv = mv^{soilmin} + a_1 \, (NPD - NPD^{dry}) \, \exp(a_2 \, g)$$

$$(1) \quad g = b_0 + b_1 \ln(NPD^{dry})$$

Determine coefficients (b_0, b_1):

- Calculation of coefficients (b_0, b_1) by setting parameter g equal to Vegetation Water Content (VWC): $g \cong VWC$

  where, VWC is calculated from Normalized Difference Vegetation Index (NDVI) (consistent with SMAP VWC ancillary data approach)

Baseline (dry) soil moisture

(2)

$$mv = mv^{soilmin} + a_1 \, (NPD - NPD^{dry}) \, \exp(a_2 \, g)$$

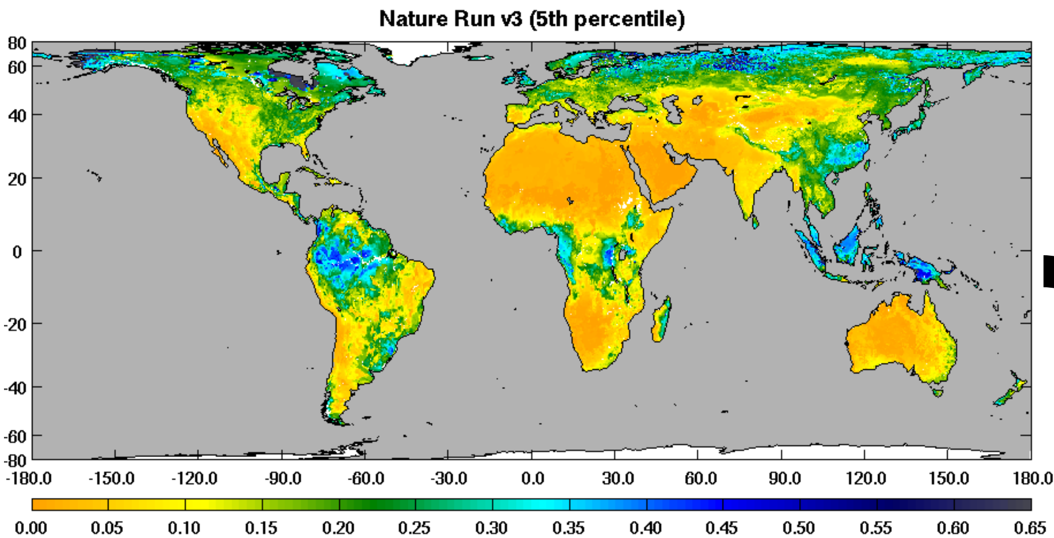
$$g = b_0 + b_1 \ln(NPD^{dry})$$

Determine 2-D array of baseline (dry) soil moisture values:

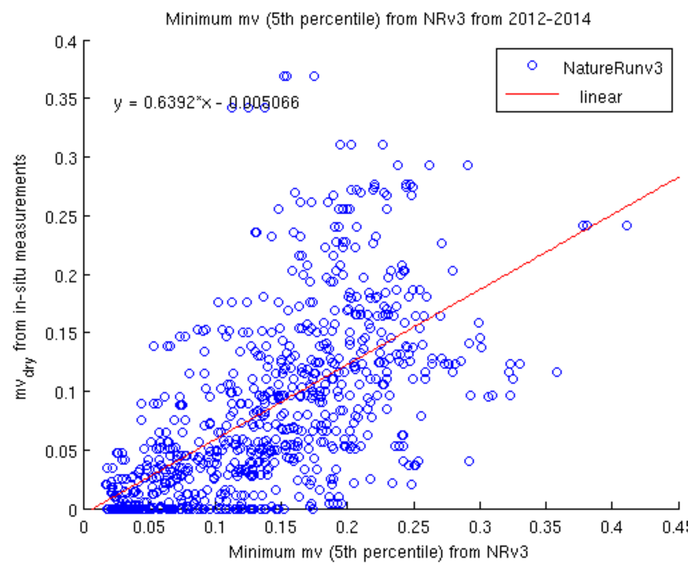
$mv^{soilmin}$ = Scaled Nature Run

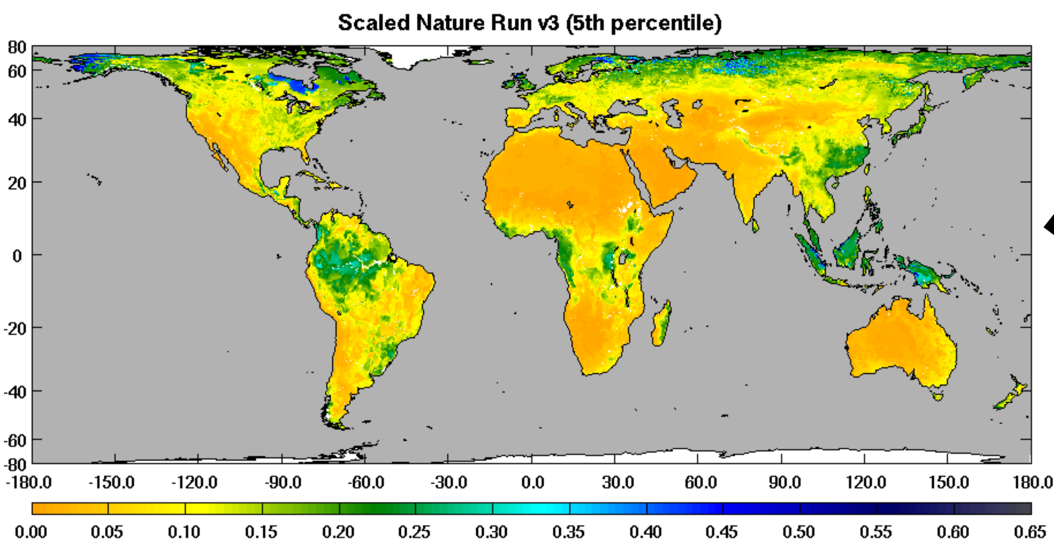
- Use 5th percentile minimum of model-based soil moisture - half-hourly Nature Run v3 (NRv3) soil moisture data from Reichle *et al.*
- Model data are calibrated (scaled) using corresponding 5th percentile of in situ soil moisture data from USCRN, SCAN and USDA LW & WG

Baseline (dry) soil moisture cont.



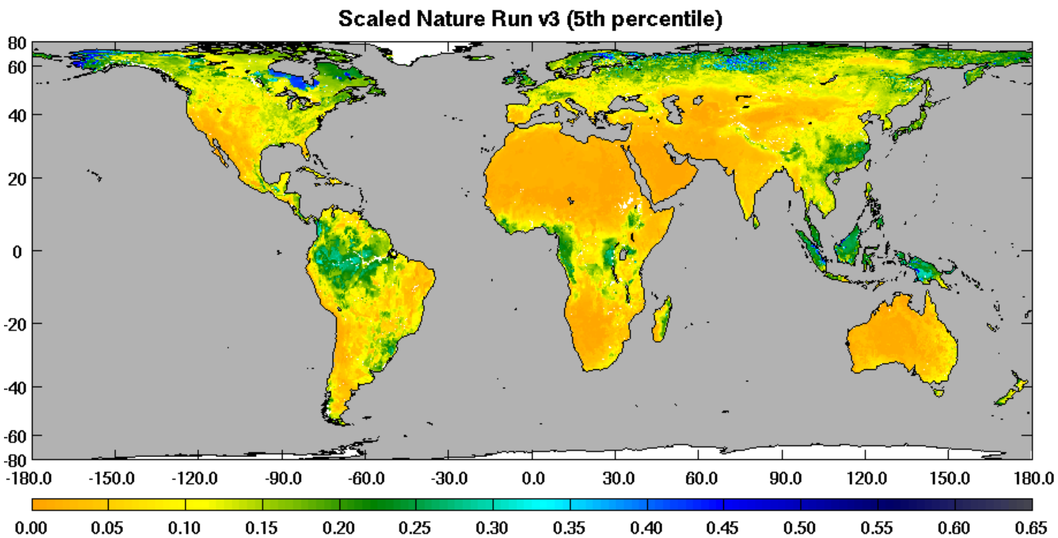
5th percentile of Nature Run



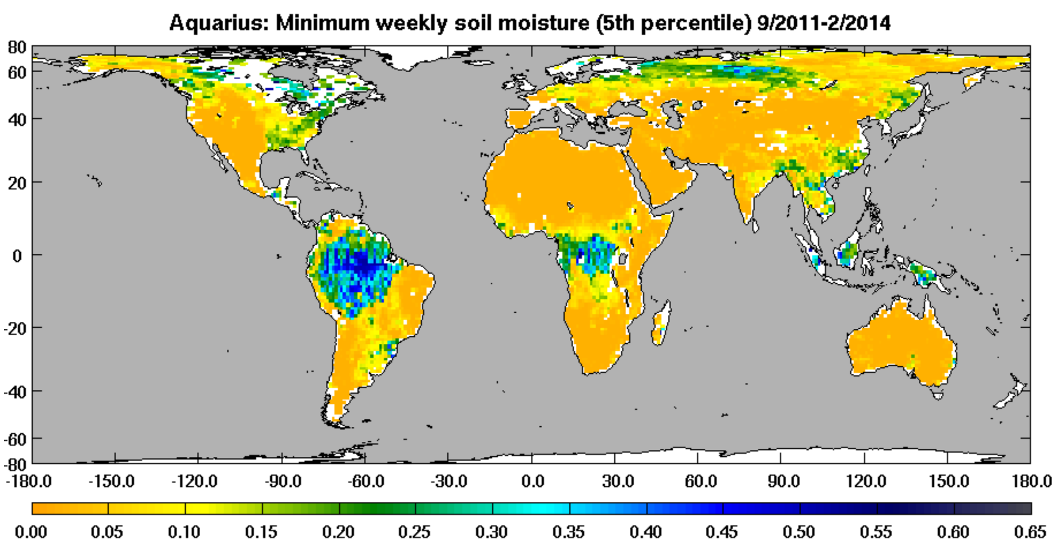


Scaled 5th percentile of Nature Run

Baseline (dry) soil moisture cont.



Scaled 5th percentile of Nature Run



Minimum weekly soil moisture (5th percentile) from Aquarius: 9/2011-2/2014

Departure from dry condition

(3)

$$mv = mv^{soilmin} + a_1\,(NPD - NPD^{dry})\,\exp(a_2\,g)$$

$$g = b_0 + b_1\,\ln(NPD^{dry})$$

with $mv^{soilmin}$ = Scaled NR, (a_1, a_2) = 2-D arrays

$b_0 = -4.3039$, $b_1 = -1.6143$ (AMSR-E)

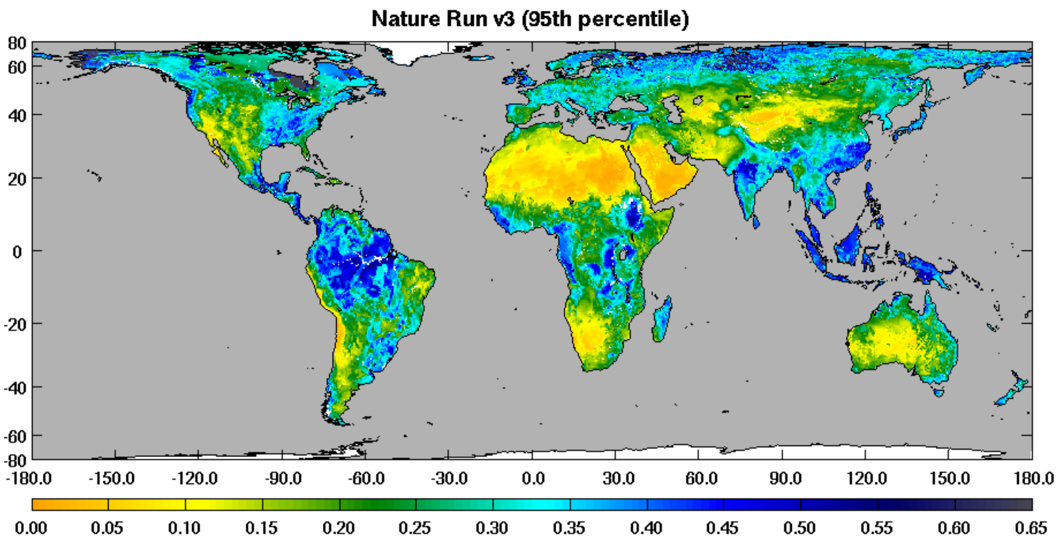
$b_0 = -4.6898$, $b_1 = -1.7151$ (AMSR-2)

Determine coefficients (a_1, a_2):

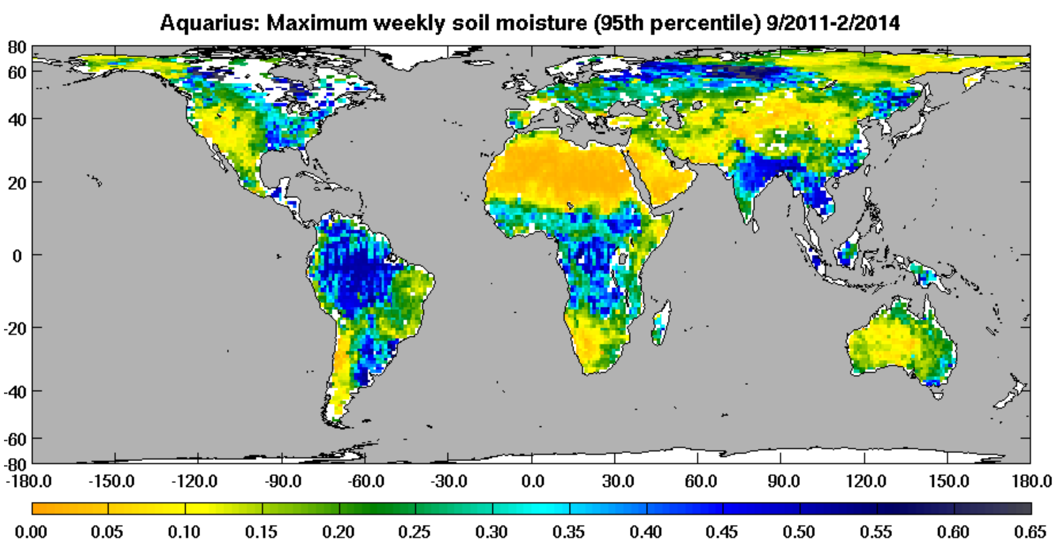
- Use Nature Run data from 2012-2014 to find maximum soil moisture condition (mv^{wet}) and AMSR-E from 2005-2009 to find NPD^{wet}

  ➔ repeat analysis for AMSR-2
- Calculated a_1 while globally assuming $a_2 = 0.3$ (to constrain estimation)

Departure from dry condition cont.

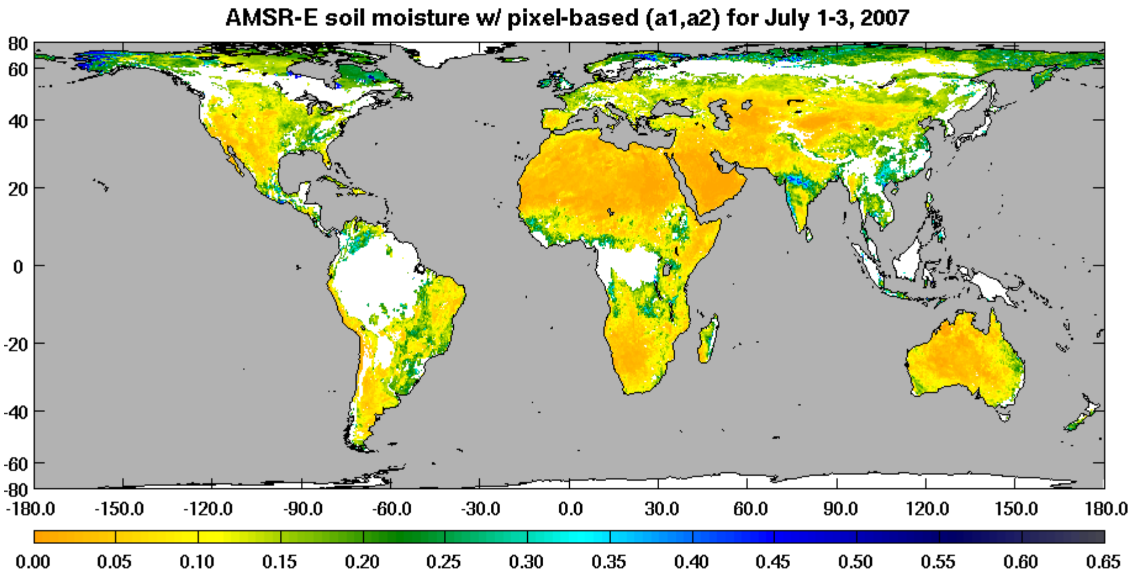


95th percentile of Nature Run



Maximum weekly soil moisture (95th percentile) from Aquarius: 9/2011-2/2014

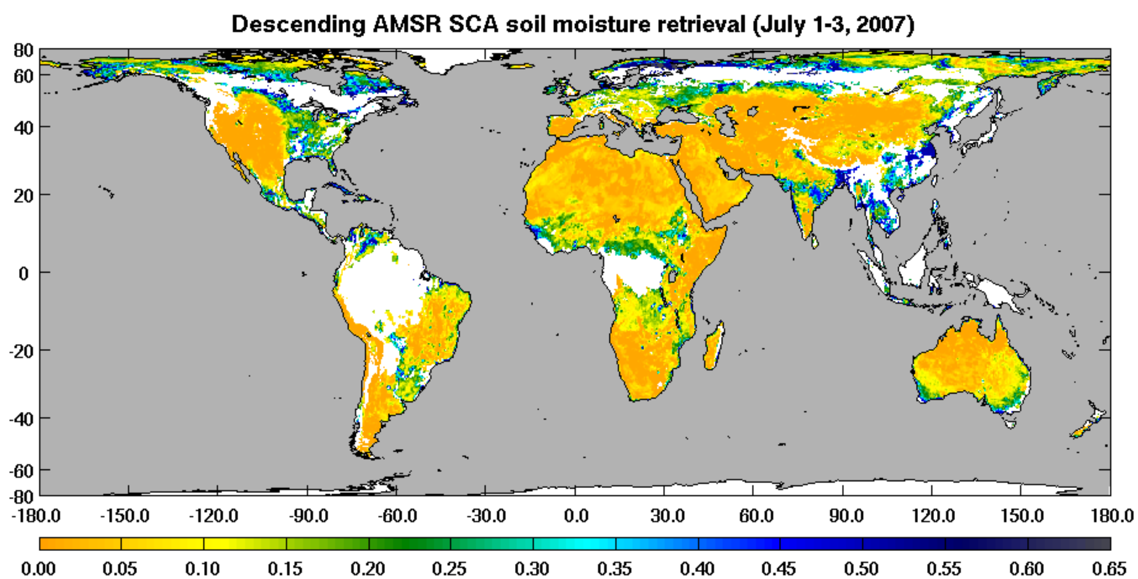
Soil moisture for July 1-3, 2007



NPD:

- Pixel-based (a_1, a_2) parameter

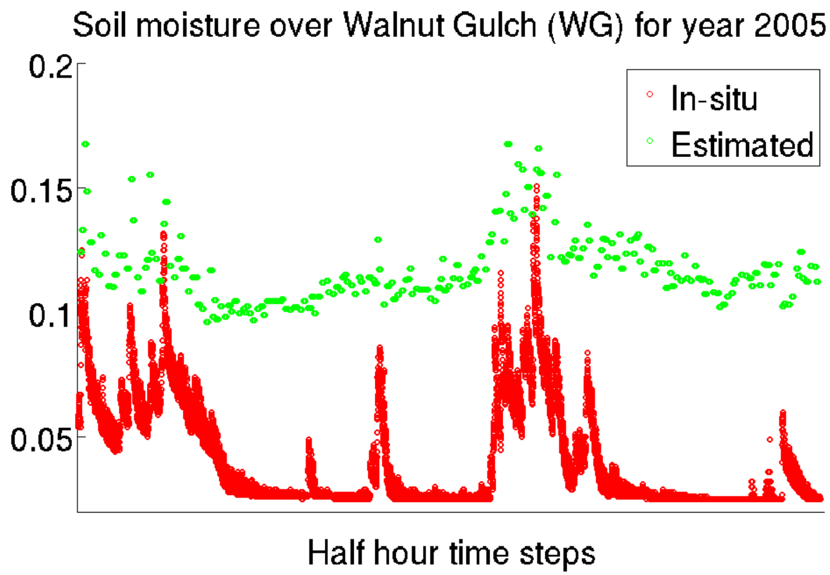
Single Channel Algorithm (SCA) soil moisture output

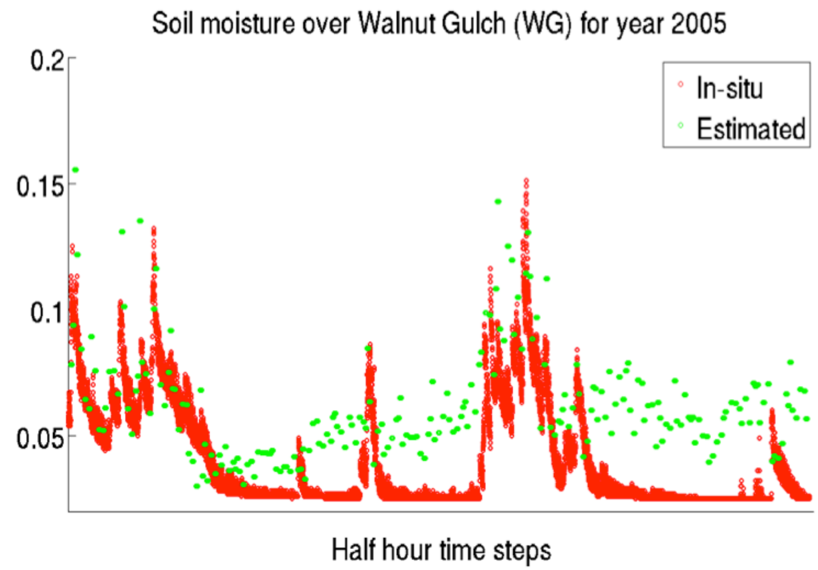


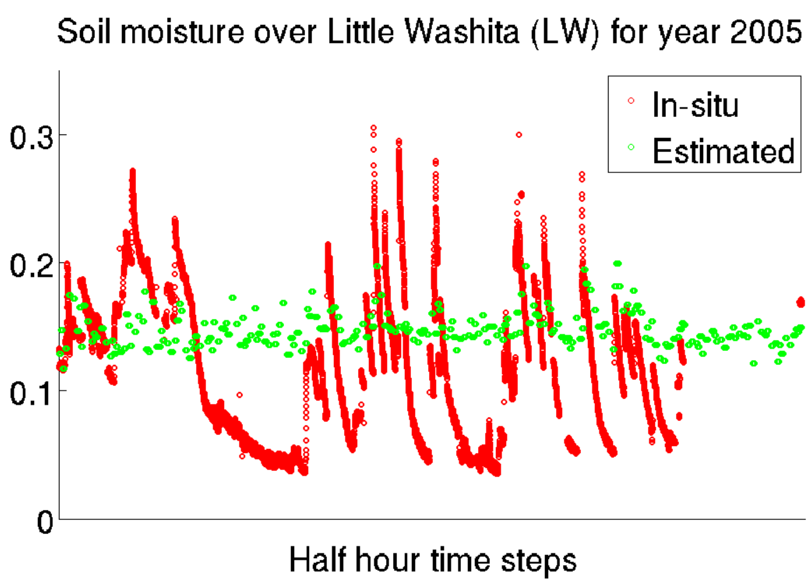
Validation with in-situ soil moisture

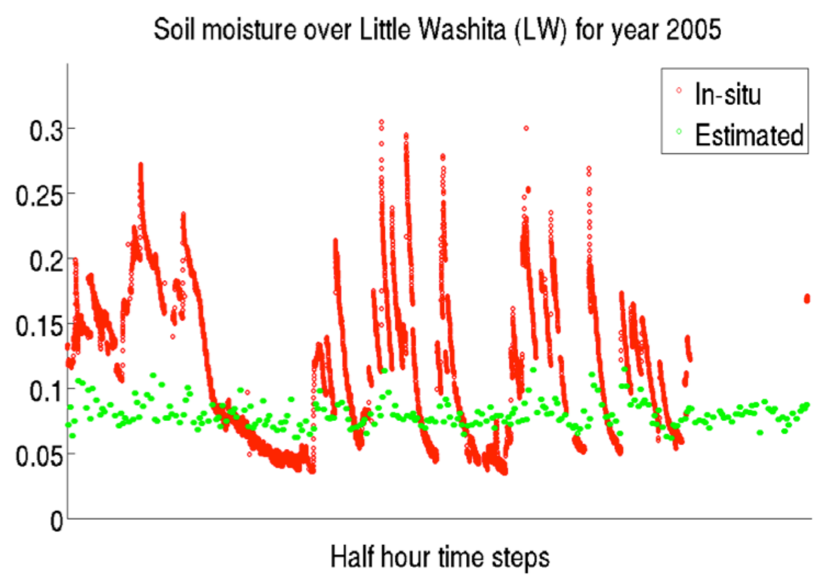
Original coefficients

Pixel-based coefficients

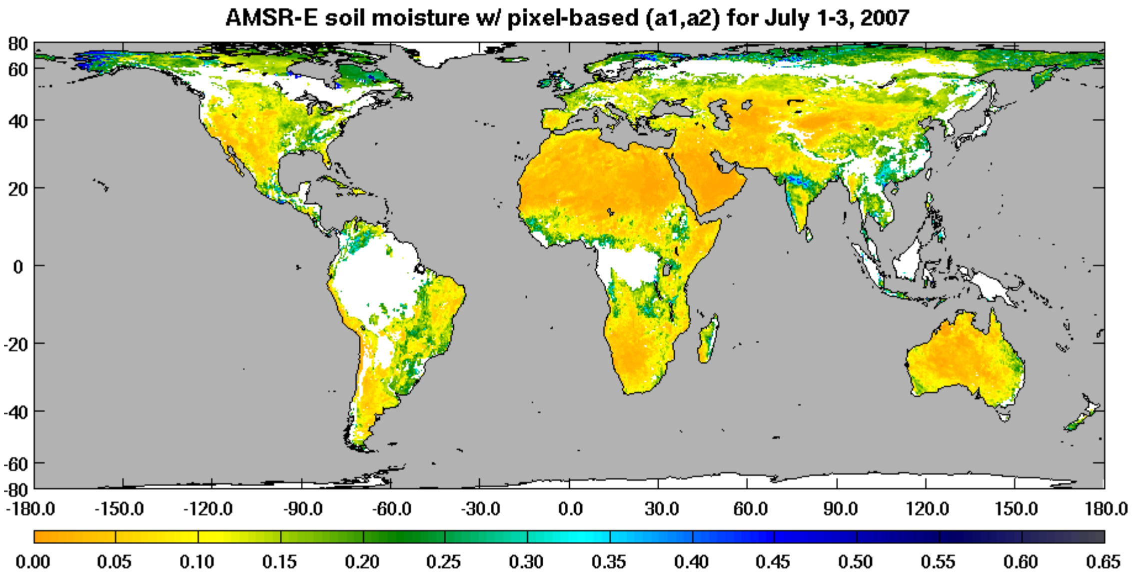








NPD for AMSR-E/AMSR2

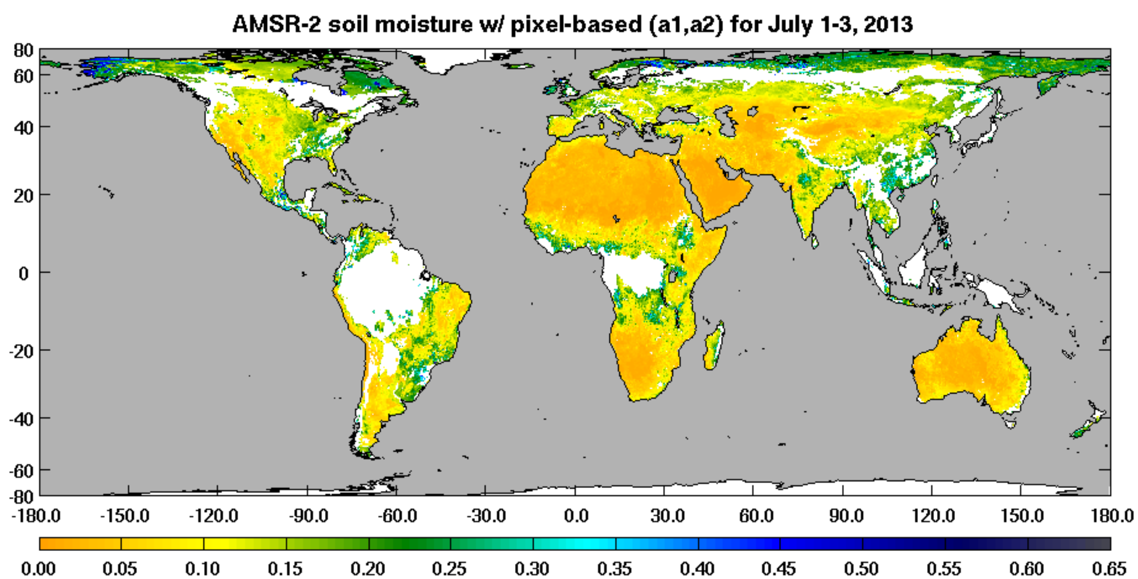


NPD for AMSR-E
July 1-3, 2007

- AMSR-E specific (b_0, b_1)
- AMSR-E specific NPD^{dry}
- Scaled Nature Run as $mv^{soilmin}$
- AMSR-E specific (a_1, a_2)

NPD for AMSR2
July 1-3, 2013

- AMSR-2 specific (b_0, b_1)
- AMSR-2 specific NPD^{dry}
- Scaled Nature Run as $mv^{soilmin}$
- AMSR-E specific (a_1, a_2)



NPD update summary

- Overall NPD equation remains the same
- NPD TB input updated from Res 1 to Res 2
- Binning updated from direct mean to inverse square distance
- NPD model coefficients updated from scalar to 2-D values
- Updated NPD model coefficients to be delivered soon

Concluding Remarks

All